Tool wear monitoring sensors

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Abstract
Tool breakage and uncontrolled wear are the main reasons for poor quality in machining of discrete components and expensive secondary costs. On-line tool wear monitoring is thus desirable in an unattended manufacturing system. It is now considered necessary to employ several types of sensors measuring different parameters associated with tool wear and to pass the information to an expert system which can make a judgement based on many factors. The environment of production line machinery is electrically very noisy and for this reason it may be desirable for many of the electrical type sensors to be replaced by optical equivalents. This paper reviews sensors suitable for tool wear monitoring.
Keywords: Tool wear, Monitoring, Sensors, Acoustic Emission, Expert System.

1 Introduction

Detection of the end of useful cutting tool life is necessary to initiate tool replacement to ensure maximum efficiency of automated advanced manufacturing systems. Also prediction of tool failure during machining is required because unexpected failure can cause damage to both machine tool and workpiece. Many different monitoring techniques have been tried and they may be classified into direct and indirect measurements.

Direct measurement
1. Optical and fibre optics with TV cameras and CCD arrays
2. Electrical resistance sensors
3. Radioactive sensors
4. Pneumatic sensors
5. Touch probes

Indirect measurement
6. Cutting force, thrust, torque, and power sensors
7. Vibration and sonic analysis (noise)
8. Acoustic emission.

All of these types of sensors have existed in electrical form since conception and are available commercially, but more recently optical fibre equivalents have

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been developed in prototype form. Optical fibre sensors can operate in hostile environments that cause problems for electrical sensors.

2 Optical

The simplest optical monitoring technique is to view the moving cutting edge with a synchronized stroboflash through a low power microscope. Progressive wear can be seen quite clearly because of the higher reflectivity of the wear land compared with the uneven surface.

Imaging is made easier by the use of a TV camera and displaying the image on a TV monitor screen. To overcome the problem of having to use bulky optical components between the cutting edge and the TV camera, a bundle of optical fibres (endoscope) can be used instead. Finally, to simplify the task of quantifying the tool wear, charged coupled device (CCD) arrays or cameras can be used to divide the image into individual pixels with areas of about fifty square microns. Thus the reflectivity or the profile of the worn tool can be digitized and a judgement can be made on the extent of tool wear based on numerical information.

Work on these systems is progressing in many laboratories but their widespread use has been delayed because the price of CCD systems has only recently fallen to an acceptable amount.

3 Electrical resistance

A change in electrical resistance due to wear of a cutting tool can be used to generate a change in an electrical output signal. The change in electrical resistance occurs because the contact area between the tool and the work piece increases with tool wear. There have been problems with resistance changes being caused by variations in cutting speed, feed and cutting forces.

Another system is to deposit a thin film resistor on the cutting tool either by printing, for example graphite ink, or evaporating chromium and using a thin insulating film of heat resisting paint. The additional cost and availability of tools with surface resistors together with additional setting up procedures and costs are obstacles to their use.

4 Radioactive sensors

An alternative technique to monitoring electrical resistance changes with wear is to monitor changes in radioactivity levels of a thin film of radioisotope deposited on the tool. A decrease in detected radioactivity means that the tool has worn and so a correlation can be obtained between radioactive particle count and tool wear. Although a good idea in principle, radioactivity in normally nonradioactive environments is not advisable practice.

5 Pneumatic sensor

Pneumatic gauging is an established technique for dimensional measurement. A suitable jet of low pressure air is directed at the surface to be measured and the change in back pressure with changing nozzle to surface separation allows dimensional changes to be measured with accuracies of the order of $\pm$ 1 μm. A